IMPRS LECTURE DAY: GQFI

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LECTURE 1

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→ INTRO: • WHO'S LECTURING?
• BE ON TIME
• DO HOMEWORKS
} WHY?

→ WHY GQFI?

GRAVITY ↔ QUANTUM FIELDS

HOLOGRAPHY (A.K.A AdS/CFT CORRESPONDENCE OR GAUGE-GRAVITY DUALITY)

↕

(QUANTUM) INFORMATION

MALDACENA 97
+ 13k FOLLOWERS*

→ WHY HOLOGRAPHY?

'THOOFT 93
SUSSKIND 94

- BECAUSE OF THE HOLOGRAPHIC PRINCIPLE
- EVERY THEORY OF GRAVITY* CONTAINS BLACK HOLES
- BLACK HOLES  BEHAVE THERMODYNAMICALLY*

$$\text{ENTROPY}_{BH} \sim \frac{\text{AREA OF BDRY}}{4G_N}$$

- BUT IN (STANDARD) LOCAL QM SYSTEMS ENTROPY ~ VOLUME
- HOLOGRAPHIC PRINCIPLE: GRAVITY AT A MICROSCOPIC LEVEL IS LOWER DIMENSIONAL: AREA in d DIM = VOLUME in d-1 DIM
'THOOFT'S DIMENSIONAL REDUCTION

QUESTIONS: • WHAT ARE THE RELEVANT MICRO THEORIES?
• WHERE DO THEY LIVE? (E.G. HORIZON?)
• WHAT IS INSIDE A BH?
• A FOLLOW-UP TO IT: DOES BH VOLUME MEASURE SIZE?

IN HOLOGRAPHIC PRINCIPLE WE SAW 2 CRUCIAL INGREDIENTS

NOTION OF A BOUNDARY ↔ ENTROPY COUNTING FOR QFTs

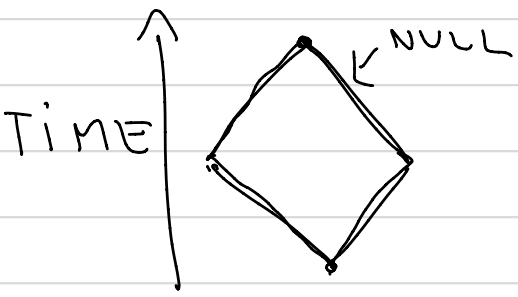
QFTs LIVE IN $R^{1,d-1}$ ↕ NON-DYNAMICAL (FIXED)

MAYBE ENTROPY THEN IS NOT = A PROP. OF BH INTERIOR BUT THE WHOLE GRAVITATING SPACETIME

A GOOD QUESTION TO ASK:

WHAT SPACETIMES HAVE $R^{1,d-1}$ AS A BDRY?

LET'S SURVEY THE MOST SYMM. SOL. OF EINSTEIN EQNS.:



MINKOWSKI

$\Lambda = 0$

FUTURE BDRY

PAST BDRY

DE SITTER

$\Lambda > 0$

ANTI-DE SITTER (AdS)

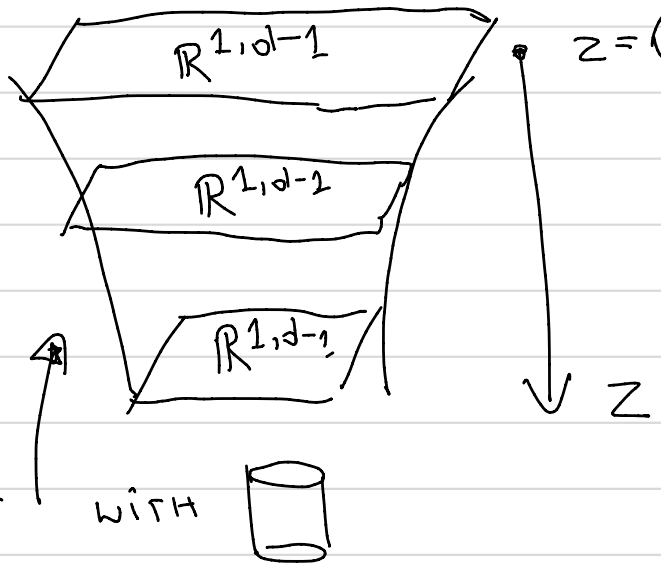
$\Lambda < 0$

CONCLUSION: AdS CAN HAVE $\mathbb{R}^{1,d-1}$ AS ITS BDRY

PROPS. OF AdS SPACE:

$$ds^2_{AdS_{d+1}} = \frac{L^2}{z^2}\left(dz^2 - \underbrace{dt^2 + dx^2}_{\mathbb{R}^{1,d-1}}\right), \quad z \in (0, \infty)$$

SCHEMATICALY:



→ EXERCISES: CONNECT WITH

$z=0$ IS THE BDRY. WHY? LIGHT RAYS CAN REACH IT IN FINITE TIME: $z = z_0 - t$, $\vec{x} = \text{const}$ ARE GEODESICS

AdS IS A BOX WITH TIMELIKE (ASYMPTOTIC) BDRY.

↑ EXERCISES

WHEN SOLV. EQNS, E.G. $R_{ab} - \frac{1}{2}R g_{ab} - |\Lambda| g_{ab} = 0$, ON TOP OF AdS WE NEED TO SPECIFY BDRY COND. FOR PROPAGATING FIELDS

E.G. SOLVING $R_{ab} - \frac{1}{2}R g_{ab} - |\Lambda| g_{ab} = 0$ GIVEN $\underbrace{g_{ab}|_{t=0} \text{ AND } \partial_t g_{ab}|_{t=0}}_{\text{SUBJECT TO CONSTRAINTS}}$

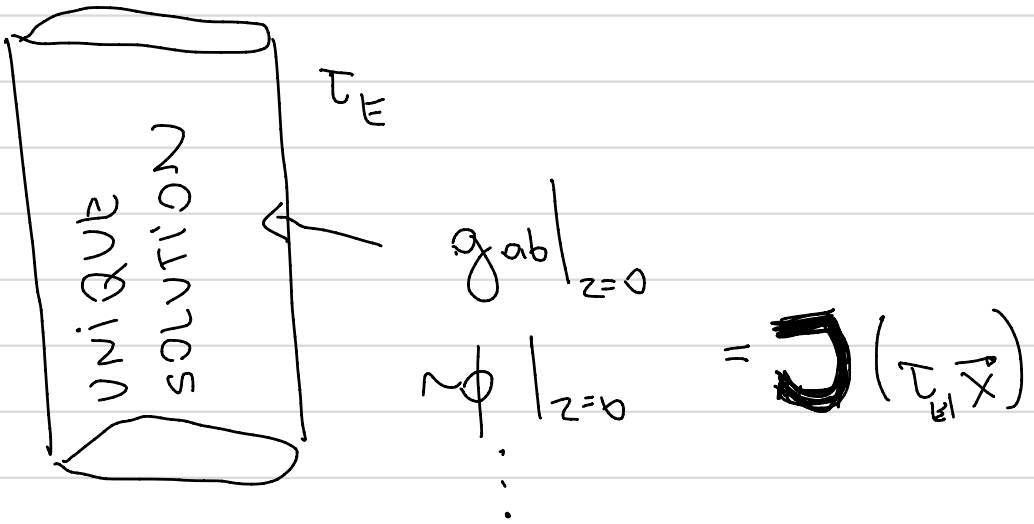
DOES NOT MAKE SENSE ALONE, WE NEED TO SUPPLEMENT IT WITH $g_{ab}|_{z=0}$

THE SAME APPLIES TO ANY OTHER FIELD LIVING IN AdS:

$$\phi \to \sim \phi|_{z=0}$$
$$A_\mu \to A_\mu|_{z=0}$$

THESE BDRY COND. ARE PHYSICAL

IMAGINE NOW THE FOLLOWING: $t \to i\tau_E$



WE CONSTRUCT THE CORRESPONDING EUCL. SOLN OF EOMs AND EVAL. THE ACTION OF GRAV. THEORY (+MATTER) ON-SHELL

$$S^E_{AdS}[\mathcal{J}] = \frac{1}{16\pi G_N} \int dz\, d\tau_E\, d^{d-1}x \left(\underbrace{R - 2\Lambda}_{\sim \frac{1}{L^2}} + \text{MATTER} + \text{G.H. TERM} + \text{COUNTER TERMS} \right)$$

2 DERIV. WHY?

FOR $\mathcal{J}=0$ WE GET $S \sim \frac{L^{d-1}}{G_N} \gg 1$

HOMEWORK ON WED ~ CENTRAL CHARGE FOR A SU(N) GAUGE THY $\sim N^2$

IN ORDER TO TRUST IT

$$e^{-S^E_{AdS}[\mathcal{J}]} \sim Z_{\text{CERTAIN CFT}}[\mathcal{J}]$$

AdS | CFT CORRESPONDENCE